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Understanding demand for higher quality sanitation in peri-urban Lusaka, Zambia through stated and revealed preference analysis

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ABSTRACT

Poor peri-urban sanitation is a significant public health problem, likely to become more important as the world rapidly urbanizes. However, little is known about the role of consumer demand in increasing peri-urban sanitation quality, especially for tenants using shared sanitation as only their rental choices can be observed in the market. We analyzed data on existing housing markets collected between 9 Jun and 6 Jul 2017 using the Hedonic Pricing Method (HPM) to capture the percentage of rent attributable to sanitation quality (n = 933). We also conducted discrete choice experiments (DCEs) to obtain willingness to pay (WTP) estimates for specific sanitation components (n = 1087), and explored the implications by estimating the proportion of plots for which improved sanitation quality would generate a higher return on investment for landlords than building a place for an additional tenant to live. The HPM attributed 18% of rental prices to sanitation (~US$8.10 per month), but parameters for several components were poorly specified due to collinearity and low overall prevalence of some products. DCEs revealed that tenants were willing to pay $2.20 more rent per month for flushing toilets on plots with running water and $3.39 more per month for solid toilet doors, though they were willing to pay little for simple hole covers and had negative WTP for adding locks to doors (-$1.04). Solid doors and flushing toilets had higher rent increase to cost ratios than other ways landlords commonly invested in their plots, especially as the number of tenant households on a plot increased. DCEs yielded estimates generally consistent with and better specified than HPM and may be useful to estimate demand in other settings. Interventions leveraging landlords' profit motives could lead to significant improvements in peri-urban sanitation quality, reduced diarrheal disease transmission, and increased well-being without subsidies or infrastructure investments by government or NGOs.

1. Introduction

While there are clear public health and economic benefits from investment in sanitation, a deficient understanding of the role of consumer demand could reduce the effectiveness of global efforts to ensure access to sanitation for all. Poor sanitation worldwide leads to an annual loss of approximately $222.9 billion USD (Corporation et al., 2016) and is the second leading cause of DALYs lost due to diarrhea (GBD Diarrhoeal Diseases Collaborators, 2017). The World Bank estimates the overall cost of bringing safe sanitation to all by 2030 to be $70 billion dollars per year, less than one-third of the annual losses caused, but 70% of that amount needed for urban and peri-urban areas and most of the burden falling on national governments and international donors, as little consumer contribution is anticipated for improving sanitation (Hutton and Varughese, 2016). However, in peri-urban settings, where up to 2 billion people are expected to live by 2035, many existing toilets are of poor quality and would be unable to take advantage of improved infrastructure (UN-HABITAT, 2003).

Residents of peri-urban areas experience poorer health outcomes across a variety of measures (Ezeh et al., 2017). Although recent work has shown some links between sanitation and health outcomes, including diarrheal disease, there is limited granular evidence of the impact of sanitation quality beyond having an improved slab, having a sewer connection, and moving from shared to single-family toilets (Freeman et al., 2017; Wolf et al., 2014). If we view the health impact of sanitation quality through a broader conceptual lens – such as the Healthy Sanitation Framework, which goes beyond simple prevention of infection to include hygiene, accessibility, desirability, sustainability, and use as key constructs (Tidwell et al., 2018a) – there is also strong evidence of sanitation quality affecting psychosocial stress and well-being via aspects like safety, privacy, disgust at unhygienic conditions, and interpersonal conflict due to collective action failure (Shiras et al., 2018).

Increasing consumer demand is a critical component of improving

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sanitation to reduce costs to governments and donors and to improve sustainability. Social marketing has shown promise in increasing demand for water and sanitation services (Evans et al., 2014b), In rural areas, the most widely-used approach (Community-led Total Sanitation, or CLTS) focuses on motivating communities to construct latrines, generally without subsidies or material provisions (Kar and Chambers, 2008), and programs seem to have achieved success in some locations (Pickering et al., 2015). There are some concerns that such demand-driven approaches may have unintended negative consequences, however, such as worsening inequality and or reducing well-being (Barrington et al., 2017). The Total Sanitation Campaign in India took the opposite approach, sanitation provision without accompanying promotion, but there is some evidence of a lack of use of many of these latrines (Clasen et al., 2014). In urban areas, it has been shown that the uptake of sewerage connections was not simply driven by socio-economic status, but that attitudes towards sanitation played a key role (Santos et al., 2011) and residents would not even pay a small fee to connect to sewerage if demand was sufficiently low (Bank, 2015). However, rigorous trials of the potential impact of increasing demand for peri-urban sanitation are limited (Evans et al., 2014a).

In peri-urban Lusaka, Zambia, about half of residents are currently without adequate sanitation (World Bank, 2015). The SanDem trial, an individually randomized controlled trial of a behavior change intervention targeting landlords with messages about increasing profitability and reducing conflict on their plots, was designed to demonstrate the potential role of demand-enhancement strategies to improve sanitation quality (Tidwell et al., 2019). Formative research identified tenant willingness to pay (WTP) increased rent for sanitation and a lack of awareness by landlords as possible levers for an intervention (Tidwell et al., 2018b). Quantifying tenant demand for specific sanitation components is needed to understand if increasing tenant demand is necessary, or if landlords simply need to be made aware of existing demand, which might in turn lead them to improve their toilets. But, measuring tenant WTP is more difficult than when direct purchases of products can be observed (as in (Burt et al., 2017)), because tenants cannot be observed directly purchasing sanitation goods in a market; they simply make rental choices where sanitation quality is one of many relevant characteristics. We specifically wanted to measure WTP for simple hole covers, flushing toilets, solid doors, and inside and outside locks to use in the behavior change messaging of the trial.

A variety of empirical techniques are available to estimate WTP, generally divided into revealed preference (RP) and stated preference (SP) methods (Breidert et al., 2006). Revealed preference methods analyze the actual choices made by consumers in markets. As tenants do not directly purchase sanitation, but instead gain access as a part of their choice of where to rent, the Hedonic Pricing Method (HPM) can be used to calculate implicit prices for each attribute based on the parameters of a regression analysis (Rosen, 1974). This approach has been applied to sanitation in diverse settings, demonstrating increases in rent associated with the presence of a toilet ranging from 1.6% (Gulyani et al., 2012) to 60% (van den Berg and Nauges, 2012), as well as increases of 16% from moving from a pit latrine to flush toilet (Knight et al., 2004) or 14% from moving from shared to private toilets (Brueckner, 2013). However, revealed preferences may be biased if choices are complex (Beshears et al., 2008), and market equilibrium values cannot be trusted when there is market failure (Hanna and Richards, 2014). RP methods can only be used in existing markets, and so cannot be applied to new products, and they are generally useful only for projecting short-run deviations from the status quo within a market (Hensher et al., 2005). HPM itself is also subject to several limitations related to choosing the correct model for demand, "missing" attribute levels or combinations of attributes, and estimating WTP separately for collinear attributes (Harrison and Rubinfeld, 1978; van den Berg and Nauges, 2012).

SP techniques can directly elicit willingness to pay, as in the Contingent Valuation Method (CVM) (Ciriacy-Wantrup, 1947; Mitchell and Carson, 1989), or observe simulated choices using constructed sets of alternatives, as in discrete choice experiments (DCEs) (Ben-Akiva and Lerman, 1985; McFadden, 1986). SP methods can be designed to obtain the exact information of interest, and though we are aware of no DCE studies estimating WTP for sanitation, CVM has been used to value sanitation in a variety of settings since the early 1990s. For example, tenants have been willing to pay from 2% of monthly household income for a flushing toilet with sewer connection in urban Ghana (Whittington et al., 1993) to 14% of their mean monthly expenditure for high-quality on-site sanitation in urban Burkina Faso (Altaf and Hughes, 1994). Rural households reported WTP of 30% of a year's income for a flushing toilet in Vietnam (Van Minh et al., 2013).

There is a long history of criticism of the reliability of SP methods, especially with regards to hypothetical bias (Hausman, 2012), which occurs when respondents answer survey questions differently than they would actually behave because of the lack of consequences from a survey response. There is good evidence for hypothetical bias in SP methods (List and Gallet, 2001; Little and Berrens, 2004; Murphy et al., 2005), but most comes from CVM studies to value non-market goods like environmental quality (Carson et al., 2001; Hanemann, 1994), about which consumers may have no market experience. There is less and inconsistent evidence about the magnitude of hypothetical bias in DCEs, with some finding higher marginal WTP from SP methods (Johansson-Stenman and Svedsäter, 2003), others suggesting they are equal (Cameron et al., 2002; Carlsson and Martinsson, 2001), and one even concluding that DCEs produced lower WTP estimates, with the role of unconscious habits biasing RP values upwards (Isacsson, 2007). In addition, DCEs have been found to reasonably predict some health behaviors (Quaife et al., 2018).

Accurate WTP estimates may be useful to policymakers to calculate the potential uptake of new sanitation products in a market (Van Minh et al., 2013) or optimal government subsidy levels to increase coverage (Whittington et al., 1993). HPM may provide a good estimate of the overall magnitude of WTP for sanitation by tenants, but due to the empirical and practical limitations of HPM, DCEs may better identify WTP for specific sanitation components (List and Gallet, 2001).

2. Methods

2.1. Study setting and population

This study was conducted in Bauleni, a peri-urban area in Lusaka, Zambia. Government demarcated plots were originally intended to be occupied by a single family, but an average of four households now live on each plot. The owner lives on the plot 80% of the time ("resident-landlord plots"), with others living nearby within the compound or neighborhood (about 10%) or outside of it (about 10%). A small number of plots are lived on only by the owner ("owner-occupied plots"), but in almost all cases, these owners are in the process of making the plot suitable for tenants as well. More detail about this setting is provided elsewhere (Tidwell et al., 2018b). The study population was limited to adult tenants and landlords on resident-landlord plots as this allowed data from both a landlord and tenant on the same plot to be collected.

2.2. Hedonic Pricing Method

Hedonic equations related the rental value of the property to characteristics of the property (Chau and Chin, 2002), including house-specific (number of rooms, rent paid) and general plot characteristics (presence of electricity and/or water on the plot, presence of toilet accessible to tenants on the plot, number of tenant households on the plot, location of neighborhood). The study covered an area with relatively homogeneous construction characteristics and included only plots with resident landlords, so other variables commonly included in such analyses, such as distance to nearest clinic or city center, building materials used for home construction, and residential status of landlord were excluded. The contribution of sanitation quality to rent was estimated using two different regression models. In the first, we used a binary indicator of whether a toilet of any kind was present on the plot (1). Second, specific measures of sanitation quality were incorporated (2) using relevant components from the Peri-Urban Healthy Toilet Index (PUHTI) score (Tidwell et al., 2018a), with measures relevant for the SanDem trial discussed separately from the rest in the results. These measures were selected in part because of the range of impacts they have on healthy sanitation from the viewpoint of the Healthy Sanitation Framework: a simple cover or flushing toilet reducing smell or fecal contamination due to flies (Desirability/Hygiene); a flushing toilet allowing a sewer connection when the proper infrastructure is constructed (Hygiene); a solid door and lock on the inside of the door providing safety and privacy (Desirability); and a lock on the outside of the door limiting access to outsiders to preserve a toilet's cleanliness and encourage tenants to clean the toilet (Accessibility).

HPM assumes that rental properties are differentiated products purchased in a perfectly competitive market at the equilibrium price, which is taken by consumers as exogenous. Several of the potential forms for the hedonic price function were assessed, including linear, log-linear, and generalized linear models. For the linear and generalized linear models, when price (or a function of price) are estimated by linear regression, the implicit prices for each component are given by the regression parameters for that component. For the log-linear model, the parameter is multiplied by the individual's value of P, with the resulting values then averaged over all individuals in the sample (to get the average implicit price for the sample) or the parameter is multiplied by the mean value of P for the sample (to get the implicit price for the average rental price in the sample). The Generalized Linear Model (GLM) is estimated by applying a link function to the price variable, which is modelled using a member of the exponential family, with both chosen to align with empirical observations. We estimated each of these models using OLS and assessed their robustness using a studentized Breusch-Pagan test for heteroscedasticity (Breusch and Pagan, 1979) to understand how to best capture the structure of rental prices. Variance inflation factors were calculated to assess multicollinearity using a cut-off value of 2. Ramsay's RESET test (Ramsey, 1969) was used to investigate the appropriateness of the functional forms of the models. After specifying the model, the overall variation in rent associated with the presence of a toilet and for specific components were calculated and are reported in Appendix A. We also compared the estimates of parameters common to the two models using bootstrapping with 1000 draws (Fox, 2002).

2.3. Discrete choice experiment design

Discrete choice experiments were developed according to published guidelines for good experimental design practices by clearly explaining attributes and levels for each choice set, using attributes and levels with which participants would already have been familiar, using realistic attribute levels, limiting the number of alternatives, eliminating implausible sets, and minimizing the number of choice tasks (Johnson et al., 2013). The primary objective was to measure WTP for specific sanitation components for tenants. DCE pre-piloting was conducted among 10 respondents during a much more comprehensive formative research study to design a sanitation demand-creation intervention (Tidwell et al., in press) in September 2016. Pre-piloting aimed to gain a qualitative understanding of the desired characteristics for improved toilet quality to identify relevant attributes and levels for DCEs and to gauge respondent limits on the number of choice tasks and attributes to vary within each task. Attributes were then selected based on the primary outcomes identified for the trial (Table 1) and piloted with 25 respondents in May 2017 to establish priors for designing the final choice sets and ensure that all selected attributes and levels were clearly understood.

Table 1
Discrete choice experiment attributes and levels.

Attribute	Levels
Door/Locks	(1) No door or locks (2) Solid door with no locks (3) Solid door with inside and outside locks
Toilet Seal	(1) Uncovered hole (2) Simple hole cover (3) Flushing toilet
Relative Monthly Rental Price Difference	(1) 0 Kwatcha (2) 10 Kwatcha (3) 20 Kwatcha (4) 30 Kwatcha (5) 40 Kwatcha (6) 50 Kwatcha

We created the piloting choice sets to be D-efficient using a Modified Federov algorithm (Cook and Nachtrheim, 1980) in *dchoice* for Stata, which improves parameter specification if accurate priors are supplied (e.g., by removing choices with very unlikely alternatives). Initial parameter values were suggested by the study team based on the rental price parameter being 1 for 10 Kw and others set based on hypothesized WTP values. The piloting results were used to produce updated priors and revised choice sets for the main data collection using the same process. The only prior that varied between the water tap/no water tap tasks was the value of a flushing toilet. A total of 6 choice sets were generated varying two categorical variables with three levels each (Door/Locks and Toilet Seal) and one continuous variable with 6 levels (Table 1), with the D-efficiency of the design being 0.608. No "opt-out" choice was included, and alternatives were unlabeled.

Tenants were asked to choose between two toilet profiles shown on cards (see Fig. 1 for an example) representing the toilets offered at two rooms available on adjacent, otherwise identical plots to reduce the impact of assumptions about room quality, plot-level amenities, and neighborhood effects. Each choice task presented different attribute levels, while holding fixed a general situational description representative of a typical plot in Bauleni. The only situational variable systematically altered was the presence of a water tap on the plot, as formative research revealed that flushing toilets were less desirable to tenants when water was scarce. Half of respondents were randomly assigned to tasks featuring plots that either both had water taps or both did not. Price differences were presented in increments of 10 Kwacha (Kw, about 1 USD) and as positive values in relative terms to reduce framing effects.

2.4. Discrete choice experiment modelling

We modelled choices using random utility models and both multinomial logit (MNL) and mixed logit (MMNL) model. An MMNL model was used in addition to a fixed-parameters MNL model as it allows regression parameters to be modelled by a random variable (a "taste" parameter), incorporate unobserved factors that are common across choice sets (such as when one respondent makes several choices in succession), and estimate WTP in a straightforward manner (Hensher et al., 2005). The model assumed that the presence of a water tap would impact WTP for water seals, but that any effects on parameters for hole covers or doors with and without locks would be small (perhaps due only to small income effects). A high_income dummy was created, with all tenants with reported income above the median (1000 Kw, or $100) coded as high income. In total, four DCE models were estimated, MNL and MMNL models with main effects only (models 3 and 4) and then

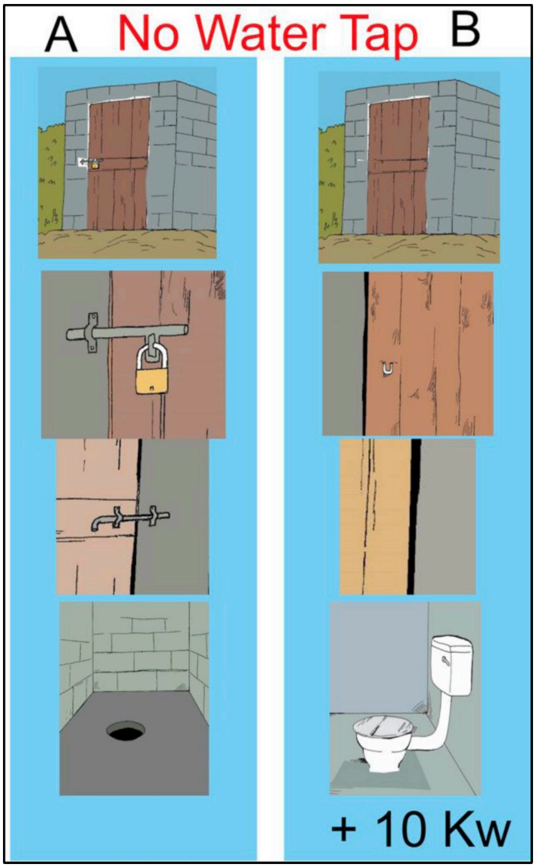

Fig. 1. A sample card used for the discrete choice experiments.

with the *high_income* dummy (models 5 and 6). The indirect utility function used for models 5 and 6 was:

$$V_{tenant;wnsj} = \beta_{toilet\_simple\_cover;w} * toilet\_simple\_cover_{sj} + \gamma_{toilet\_flushing;w} * toilet\_flushing_{sj} + \beta_{toilet\_solid\_door} * toilet\_solid\_door_{sj} + \beta_{toilet\_solid\_door\_and\_locks} * toilet\_solid\_door\_and\_locks_{sj} + \beta_{price} * price_{sj} + \beta_{high\_income} * high\_income_{sj} * price_{sj} + \varepsilon_{nsj} \quad (5 \text{ and } 6)$$

with water tap status w for individual n, choice set s, and alternative j; generic parameters β for attributes that do not vary by presence of a water tap; and attribute-specific parameters γ for those that do. Models 3 and 4 were simply estimated in the same way, but without the *high_income* interaction term. WTP was calculated by dividing each improvement parameter by the price parameter (β_{price}) to obtain the mean WTP for tenants in the sample. Confidence intervals for these WTP values were constructed using the delta method (Hole, 2007). Analysis was conducted using the *mlogit* package version 0.2–4 for R (Croissant, 2013) and maximum likelihood estimation with 500 Halton draws was performed. We also compared DCE WTP estimations to those from the HPM model including toilet quality measures (2) using t-tests due to convergence challenges with bootstrapping MMNL models.

We then explored the implications of landlords investing optimally based on this WTP by calculating the estimated rental increase per tenant household to improvement cost ratios for flushing toilets, solid doors, and building a living space for an additional tenant. Then, using the potential increased rental income per tenant for toilet improvements and the underlying prevalence of those improvements for plots with the given number of tenant households, the potential gains from landlords investing in solid superstructures and flushing toilets to gain optimal return on investment were calculated and then aggregated across the entire sample.

2.5. Data collection and analysis

Data was collected for 1085 tenant-landlord pairs between 9 Jun and 6 Jul 2017 during baseline data collection for the SanDem trial (Tidwell et al., 2019), with a sample size based on detecting a five percentage point change in four primary outcomes measuring sanitation quality with a power of 80% and a confidence of 95%. Systematic random sampling of every fourth plot in the compound was used to select plots for the study, and the landlord and a randomly selected adult tenant head of household were surveyed on each plot. Trained enumerators collected data using tablets and ODK collect software (Hartung et al., 2010). Enumerators were trained on administering study tools, pilot testing was conducted to ensure that procedures were understood and questions were unambiguous, and pilot data was used to assess the reliability of observational measures and to establish prior estimates for use in the discrete choice experimental design. All data were analyzed using R version 3.4.1 (Team, 2014).

2.6. Ethical approval

Prior to enrollment, enumerators read an information sheet to respondents in English or one of two local languages (Nyanja or Bemba) as requested by the respondent, answered any questions raised, and obtained written consent for participation. Respondents were given a copy of the information sheet to keep, and no compensation was provided for participation. Names and government-issued plot numbers were collected for the purpose of surveying the same respondents at baseline and endline, but were removed from final data sets to protect anonymity. Ethical approval for this study was provided by the London School of Hygiene and Tropical Medicine (ref: 12157) and University of Zambia Biomedical Research Ethics Committee in Lusaka, Zambia (ref: 002-02-17).

3. Results

3.1. Sample characteristics

The final combined data set of paired landlords and tenants ($n = 933$ pairs from the 1085 enrolled plots) with complete data for each variable included in the model was used to estimate the implicit prices of housing components using HPM. We also excluded tenants paying no rent from the analysis ($n = 14$, usually family members of the landlord).

Descriptive statistics for landlords, tenants, and household characteristics are given in Table 2. The typical plot was occupied by a landlord household and 3 [IQR: 2–4] tenant households. Tenants paid a median monthly rent of 450 Kw (~45 USD) from a median income of 1000 Kw (~100 USD). Most plots had a toilet (97.2%), and many had an improved slab (76.8%), but the main variables of interest to the trial were absent from most toilets.

3.2. Revealed preference: hedonic pricing model

Monthly rent was highly skewed, and even a log transformation failed a Shapiro-Wilk test of normality ($W = .962$, $p < .001$), so a generalized linear model was used for each of the hedonic pricing models and the results are given in Table 3. The WTP results from the DCEs (3) are also reported here for ease of comparison, but described in the subsequent section.

Parameter estimates for all plot and house characteristics, but not neighborhood effects, were significant at the 95% level for (1) (Table 3). The impact of having a toilet on the plot was large and statistically significant (mean: 79.1 Kw, $p < .001$). The estimated WTP per room present in the rented space is the largest contributor to overall WTP (176 Kw/room), and the presence of electricity (26 Kw) and water (49 Kw) on the plot are also statistically and practically significant.

Table 2
Variables included in willingness to pay models.

Variable Name	Description	Coding	Included in which models			Sample Characteristics	
			HPM – Toilet Presence (1)	HPM – Toilet Quality (2)	DCE (3–6)	Landlords	Tenants
Age	Age in years	Integer				45 [IQR: 34–56]	29 [IQR: 24–36]
Gender: Female	Gender of respondent	Binary				70.6%	77.4%
Education: Primary or Less	Has completed no more than primary school	Integer				28.9%	17.9%
Education: Some or Completed Secondary	Has completed more than primary school	Integer				66.3%	75.9%
Tenant Monthly Rent	Total rent paid by tenant—included in HPM as dependent variable	Integer	x	x			450 Kw [IQR: 350–550]
Tenant Monthly Income	Total monthly income for tenant—used to determine high_income below	Integer			x		1000 Kw [IQR: 750–1700]
Plots							
households	Number of separate tenant households living on plot in addition to landlord	Integer	x	x		Median: 3 [IQR: 2–4]	
rooms	Number of rooms in surveyed tenant household	Integer	x	x		1: 24.6% 2: 61.4% 3: 10.3%	
electricity_on_plot	Presence of an electrical connection on the plot and used by the tenant	Binary	x	x		38.2%	
water_on_plot	Presence of a water connection on the plot and used by the tenant	Binary	x	x	x	41.4%	
zone	Neighborhoods defined by survey team using natural boundaries (roads, markets)	Categorical (A-F)	x	x		A: 15.8% B: 15.1% C: 13.9% D: 19.2% E: 17.8% F: 18.2%	
Toilet components from PUHTI, but not of interest to trial							
has_toilet	Presence of a place for tenants to defecate on the plot, regardless of type or quality	Binary	x	x		97.2%	
toilet_solid_walls	Concrete or wooden walls surrounding toilet	Binary		x		87.5%	
toilet_solid_roof	Solid roof without holes above toilet	Binary		x		49.6%	
toilet_improved_slab	Improved toilet slab	Binary		x		76.8%	
toilet_vent	Ventilation pipe	Binary		x		17.7%	
Toilet components from PUHTI, and of interest to trial							
toilet_simple_cover	Simple hole cover (plastic flap or piece of wood or metal)	Binary		x	x	6.3%	
toilet_flushing	Water-sealed, flushing toilet	Binary		x	x	15.8%	
toilet_solid_door	Solid door on toilet structure, attached and without holes	Binary		x	x	74.7%	
toilet_solid_door_and_locks	Solid door attached, without holes, and with both internal lock (sliding bolt) and external lock (sliding bolt and padlock)	Binary		x	x	27.7%	
high_income	Tenant income greater than sample median	Binary			x		
price (dependent variable)	Total rent paid by tenant (HPM) or relative difference in rent prices between choices (DCE) measured in Zambian Kwacha (~10 Kw = 1 USD)	Integer	x	x	x		

*water_on_plot only included as interaction with flushing toilet.

Though the number of tenant households on the plot is statistically significant, its total negative impact on price is small, as the median number of households per plot is 3 (IQR: 2–4).

The magnitudes of parameter estimates for (2) were generally similar to those of (1) for plot, tenant, and neighborhood effects (See Appendix A, Table S1). However, the value of simply having a toilet on the plot dropped dramatically, with the presence of solid walls and a solid roof driving a large portion of WTP associated with sanitation quality. None of the parameters for toilet components included in the associated trial were statistically significant, possibly due to small overall magnitudes of the estimates (for simple hole covers, ventilation pipes, and inside locks), low overall prevalence reducing parameter specificity (for flushing toilets), and collinearity (for solid doors with solid roofs and solid walls—a model estimated without the latter two parameters leads to large WTP for a solid door). Presence of an outside lock is not far from statistical significance (p = .094), but the negative estimate suggests that it is actually a disincentive for tenants to live on a plot, perhaps because it restricts access to outsiders but also makes their own access more difficult. As the WTP estimates for specific components were of particular interest for the study, references to HPM results for the remainder of this paper refer to WTP values from (2), with detailed toilet quality included, unless otherwise specified.

Formative research suggested that tenants had lower WTP for a flushing toilet if there was no water tap on the plot, and (2) suggests

Table 3
Willingness to pay estimation results for Hedonic Pricing Models and Discrete Choice Experiments.

	Dependent variable:					
	price (Willingness to Pay in Monthly Rent)					
	(1)		(2)		(3)	
	Estimate	(std. err.)	Estimate	(std. err.)	Estimate	(std. err.)
households	−3.73**	(1.74)	−2.93*	(1.73)		
rooms	176.42***	(5.69)	169.58***	(5.78)		
electricity_on_plot	26.33***	(8.38)	21.69***	(8.38)		
water_on_plot	49.24***	(7.73)	38.50***	(8.46)		
zone: A (ref)						
zone: B	−1.69	(12.47)	5.78	(12.46)		
zone: C	−15.83	(11.89)	−20.10*	(11.80)		
zone: D	−14.69	(11.72)	−6.32	(11.71)		
zone: E	4.11	(12.87)	11.05	(12.76)		
zone: F	−4.50	(11.56)	4.08	(11.64)		
Toilet Characteristics (not of interest to trial)						
has_toilet	79.13***	(14.06)	22.58	(15.94)		
toilet_solid_walls			47.78***	(11.79)		
toilet_solid_roof			22.08***	(7.44)		
toilet_improved_slab			4.94	(9.18)		
toilet_vent			13.31	(10.47)		
Toilet Characteristics (of interest to trial)						
toilet_simple_cover			7.10	(15.35)	3.99**	(1.65)
toilet_flushing			8.11	(20.46)	12.66***	(3.00)
toilet_flushing * water_on_plot			8.38	(24.48)	9.39**	(3.89)
toilet_solid_door			3.50	(10.18)	33.78***	(1.81)
toilet_solid_door_and_locks			−8.82	(10.28)	−10.69***	(2.86)
Constant	38.21**	(17.43)	44.50**	(17.37)		
Observations	933		933		1085	

Note: *p < .1; **p < .05; ***p < .01.

that WTP on a plot with a water connection (16.5 Kw) may be higher than one without a connection (8.1 Kw). But, the rarity of flushing toilets in the general sample (15.9%), and especially flushing toilets with no water tap on the plot (4.6%), means that parameters for flushing toilets and the interaction term are poorly specified.

While (1) and (2) provide strong evidence of tenant WTP for sanitation, hedonic pricing poorly estimates parameters for many components of interest to the trial and to policy makers.

3.3. Discrete choice experiments

A series of four models were estimated using fixed and random parameters with and without income interaction terms based on data from all enrolled tenants (n = 1087) (Table 4). All main effects parameter estimates were significant across the four models. Due to model 6 having the lowest AIC3 value (Andrews and Currim, 2003), subsequent analysis is based on its results.

The results of estimating WTP from the mixed model with income interactions (model 4) based on the delta method are given in Table 3. All WTP values were statistically significant and well estimated, and suggest positive and practically significant WTP for solid doors and flushing toilets, negative WTP for the addition of inside and outside locks as well that WTP for a flushing toilet is greater on plots with water taps present, consistent with our hypotheses.

3.4. Implications: ranking sanitation investments

We then assessed how sanitation investment was prioritized among other common plot improvements compared to which produced a better return on investment. Based on interviews with landlords and masons in the area (Tidwell et al., 2018b), we estimated that a typical 2-room home costs about 10,000 Kw to build, a solid toilet structure with a simple lined pit costs about 2000 Kw to build, and installing a flushing toilet in addition to the solid structure costs about 3000 Kw total. Using figures from the models above, we estimated the monthly rent paid per 2-room home on plots with electricity and water (444 Kw, less 3 Kw for each home on the plot, from (2)), marginal rent for simply having a toilet (22.6 Kw, from (2)), having one with all improvements made (56.5 Kw, from subtracting the average value of a toilet in (1) from the value in (2)), and having a toilet with an improved superstructure (36.3 Kw, from subtracting the DCE value for a flushing toilet from the previous value for a toilet with all improvements made).

The amount of additional rent received in a year given the number of households on the plot were calculated without a time-discounting factor, as they are for comparison across investment options only (Table 5). This slightly understates the advantage a cheaper improvement might have, as it may take longer obtain funds or build a more costly investment. There may also not be enough space on plots to build more living spaces, so toilet improvements may be the only option in some cases. As toilets are quicker and cheaper to construct than additional living space, we find that any plot with at least three households should invest in a both a solid structure and a flushing toilet. This would increase the prevalence of solid superstructure, including walls, roofs, and doors, from 42% to 72% and flushing toilets from 15% to 58%. Though these figures are only estimates, the potential magnitude of the impact is clear, especially for the important government priority of constructing toilets that can connect to future sewerage improvements.

Table 4
Estimation results for discrete choice models.

	Dependent variable:			
	choice			
	Fixed Parameters Main Effects	Fixed Parameters Price Interaction	Random Parameters Main Effects	Random Parameters Price Interaction
	(3)	(4)	(5)	(6)
toilet_simple_cover	0.11 (0.05)**	0.10 (0.05)*	0.13 (0.06)**	0.12 (0.06)**
toilet_flushing	0.39 (0.10)***	0.36 (0.10)***	0.40 (0.12)***	0.36 (0.12)***
toilet_solid_door	1.23 (0.10)***	1.21 (0.10)***	1.39 (0.11)***	1.36 (0.11)***
toilet_solid_door_and_locks	0.90 (0.14)***	0.84 (0.14)***	0.97 (0.16)***	0.90 (0.16)***
price	0.34 (0.03)***	0.33 (0.03)***	0.39 (0.03)***	0.38 (0.03)***
toilet_flushing * water_on_plot	0.28 (0.09)***	0.31 (0.09)***	0.36 (0.11)***	0.39 (0.11)***
price * income_highlow		0.01 (0.02)		0.01 (0.02)
Parameter standard deviations for random parameters models:				
toilet_simple_cover			0.002 (3.19)	0.002 (3.04)
toilet_flushing			−0.002 (4.54)	−0.002 (4.47)
toilet_solid_door			−0.01 (2.17)	0.02 (1.58)
toilet_solid_door_and_locks			0.95 (0.08)***	0.93 (0.09)***
price			0.10 (0.04)***	0.11 (0.04)**
toilet_flushing * water_on_plot			−0.003 (3.45)	0.004 (3.60)
price * income_highlow sd				0.01 (0.49)
AIC3	7638.9	7401.5	7522.9	7298.1
Observations	6313	6127	6313	6127
Log Likelihood	−3810.47	−3690.26	−3743.46	−3628.06

*Note**p < .1; **p < .05; ***p < .01.

4. Discussion

4.1. Comparison of willingness to pay estimates

DCEs (6) and HPM (2) produced generally similar WTP estimates (See Appendix A, Table S2), though some HPM parameter estimates were poorly specified. This latter feature was expected, since collinearity of toilet components and low prevalence of certain toilet components led to poorer parameter specification compared to the statistical efficiency possible through stated preference designs. DCEs yielded practically and statistically significant estimates for WTP for flushing toilets and solid doors, and even a small, but statistically significant WTP estimate for a simple hole cover. The same patterns of increased WTP for flushing toilets on plots with water taps present and decreased WTP for adding both an inside and outside lock from HPM occurred in DCEs. WTP values for flushing toilets were similar between HPM and DCEs. WTP for doors with no locks appears higher in the DCEs than in HPM. However, the high correlation observed between solid doors and solid walls ($R^2 = .56$) as well as the relative infrequency of solid doors without solid walls (1.4%) suggests that values for doors and walls from HPM may be poorly separated.

Examining these results compared to the broader literature suggests that similar prioritization of sanitation investment by landlords in other settings may be appropriate. The magnitude of willingness to pay estimates from this study for the simple presence of a toilet (15.8%) were slightly lower than similar studies using HPM in Togo (20%) (Choumert et al., 2015) and Uganda (26%) (Knight et al., 2004), though extremes ranging from 1.6% in Kenya (Gulyani et al., 2012) to 60% in Sri Lanka (van den Berg and Nauges, 2012) have also been reported. Rates as high as paying 30% of one's annual salary for a toilet have also been reported by stated preference surveys (Van Minh et al., 2013). Moving from the most basic temporary toilet (without any quality measures from (2)) to one meeting all of these measures would result in an increase in rent of 16% of their monthly expenditures, which is also similar to findings from Burkina Faso (14%) (Altaf and Hughes, 1994) and Uganda (16%) (Knight et al., 2004). Therefore, there should be confidence that the overall magnitude of the estimates generated from HPM are reasonable. However, no previous revealed preference study of which we are aware was able to estimate WTP for more detailed components of sanitation, which is a particular concern for improving peri-urban shared sanitation quality and in evaluating the economic case for investment in areas with such heterogeneous existing sanitation quality, and thus the need for deploying the DCEs. Further, the validation of stated preference results with revealed preference approaches gives confidence that these stated preference techniques are reliable for policymakers.

Table 5
Percent of landlord investment recovered annually for plot improvements and baseline prevalences.

Number of Tenant Households on Plot	Cost recovered in one year for building:			Prevalence of Plots with Given Number of Tenant Households	Proportion of Plots with Given Number of Tenant Households That Have:	
	Another Living Space	Solid Superstructure	Flushing Toilet		Solid superstructure	Flushing Toilets
1	53%	22%	26%	22%	66%	15%
2	53%	44%	53%	28%	73%	15%
3	52%	65%	79%	20%	70%	12%
4	51%	87%	106%	12%	77%	14%
5 or more				18%	80%	17%

4.2. Improving health through increasing peri-urban sanitation quality

It is feasible that public health gains can be achieved by targeting landlords with messages about investing in sanitation quality improvements, so such messaging should be considered for all city-wide sanitation plans. Improving peri-urban toilet quality was a more profitable investment for landlords with several tenant households on their plot than more common options such as constructing new or expanding existing tenant living spaces. Tenants valued both toilet structural components of the toilet superstructure (including roofs, walls, and solid doors) and flushing toilets, which offer a more hygienic interface, reduced pathogen transmission from flies, and reduced odors during use. This finding suggests a major opportunity to improve sanitation by increasing demand, as 40% of landlords in this setting believed that tenants were unwilling to pay anything for any increase in sanitation quality (Tidwell et al., 2018b). Existing demand may close half of the gap that exists for reaching full coverage of toilets with solid superstructures and flushing interfaces, resulting in sizable reductions in diarrheal disease transmission (Freeman et al., 2017; Wolf et al., 2014) and improvements in well-being (Shiras et al., 2018). The remaining gap will also cost less to eliminate, through both a reduced number of households to be reached and the smaller per-household magnitude of any necessary subsidies, and demonstrates the possible additional impact if demand creation programs also seek to increase levels of tenant WTP. It is also more likely that these sanitation gains will be sustained if there is consumer demand for such improvements. Further data will be collected about changes in landlord perceptions of WTP and its association with SanDem trial outcomes to strengthen the evidence for the role of demand in improving sanitation quality.

This has major implications for improving peri-urban sanitation globally with some limitations based on local conditions. First, there is formal, documented land ownership in this setting, but we think it is likely that targeting profit motives for improvement may be less effective in areas where residents fear that the government may displace them at will. Second, the magnitude of the variables affecting the economic case for improving sanitation may differ elsewhere, either because materials or labor are more expensive or because tenants have less income or are relatively less interested in improving sanitation. Further investigation into these aspects of peri-urban sanitation may inform the significance of these findings for meeting the SDGs. Still, it seems likely that targeting landlord profit motives will be an essential component of peri-urban development at some point in time in most settings.

4.3. Measuring peri-urban sanitation demand

This study revealed several shortcomings of using HPM to measure demand for aspects of sanitation. HPM has been used successfully to assess WTP for the presence of a toilet in a peri-urban setting (Simiyu et al., 2017), and the price-taking assumption seems reasonable based on the limited power for tenants to negotiate rent prices due to high turnover and low inventory observed in the study setting (Tidwell et al., 2018b). However, collinearity, low prevalence, and the small magnitudes of WTP for some components of interest limit its usefulness to assess WTP for sanitation quality. The effectiveness of HPM is further impeded by the challenge of pre-specifying an appropriate demand model and the likelihood of market failure in a context where large numbers of landlords perceive no tenant demand for sanitation quality. Still, it is a useful procedure to establish an estimate of the overall magnitude of the total contribution of sanitation to rental prices, which may be combined with relative values from DCEs to improve estimates of WTP for sanitation components. Unfortunately, more advanced joint model estimation is hindered by a lack of data on the available housing options not chosen by tenants, and more complicated analytic approaches stretch the validity of the underlying data and assumptions (McConnell, 2011).

Discrete Choice Experiments may be a useful tool in future sanitation demand assessments. Though the number of components to include must be limited for respondents to make meaningful choices, the small hypothetical bias observed in this setting is encouraging. DCEs likely lead to respondent fatigue more quickly than more straightforward questions, but the specificity and quality of information generated make them a valuable tool for future applications. In particular, they are reliable demand assessment tools without requiring actual purchases to be made in a way that is able to detect small changes due to the high accuracy of parameter estimates generated. They are also simple to administer, and the impact of messaging is assessed immediately. The potential use of these techniques for assessing demand for new or uncommon technologies also makes them ideally suited to understanding the potential for transferring demand creation interventions to new settings and as market research tools for both the public and private sectors.

5. Conclusion

We have estimated tenant willingness to pay for several important aspects of peri-urban sanitation quality in our study setting. We find that landlords on any plot with at least three households should invest in a both a solid structure and a flushing toilet to maximize their profits. If all landlords practiced this, the prevalence of solid superstructure, including walls, roofs, and doors, in our study community would increase from 42% to 72% and flushing toilets from 15% to 58% without any subsidy or donated infrastructure. The magnitude of these results imply that a demand-side intervention may motivate landlords to improve their own sanitation by revealing sizable latent demand from tenants and that the potential gains of such an intervention are significant for reducing diarrheal disease transmission and improving well-being. Further, the consistency of the results with estimates from revealed preference techniques suggests the usefulness of Discrete Choice Experiments to estimate willingness to pay for other aspects of sanitation or the same components in other settings. Based on these methodological and empirical findings, consumer demand approaches can play a major role in achieving safely managed sanitation for all, and thus improve public health.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2019.04.046.

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